NEW

3.8 NUTRITION STRATEGIES TO MITIGATE YIELD LOSSES FOLLOWING WATERLOGGING

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KEY MESSAGES

- Despite presenting with some waterlogging symptoms, faba beans and canola yielded exceptionally well. It is critical to understand the crop growth stage during waterlogging to determine potential yield impacts.
- Nutritional products applied did not influence grain yield except for the trial at Hagley, Tasmania, where a yield response was observed with different rates of nitrogen applied.
- Established plants will be most affected when they are rapidly growing, for example prolonged waterlogging during the warmer spring period is where yield penalties will be most severe.

Keywords: waterlogging, nutrients, canola, wheat, management techniques

BACKGROUND

Waterlogging issues and drainage solutions are a high priority for farming systems in the high rainfall zone (HRZ) of Victoria and Tasmania. In 2021 these areas experienced a higher-than-average rainfall season, particularly through the winter months of June and July.

Waterlogging creates a stressful environment for plants to grow in and can result in reduced yields, and in severe cases plant death. Waterlogging occurs in various degrees and the definition of a waterlogged soil is the air spaces in the soil are saturated and no longer contain oxygen, forcing anaerobic conditions (Ag Vic 2020). This also diminishes the plant's ability to uptake nutrients and water through its root system. If this is occurring, plants often show reduced growth and display symptoms such as yellowing leaves, known as chlorosis (Figure 1). The growth stage of the crop during a waterlogged period is essential to understanding the effects it can have on final grain yields. Waterlogging close to sowing will affect germinating seeds and young seedlings, and as these plants do not have a well-established root system, this can have severe effects. If a soil is waterlogged during June - July in south-west Victoria or Tasmania and the crop is well established, final yields may not be severely impacted, as soils are cold, the demand for oxygen is low, and plant growth is slow (Soil Quality, 2022). Established plants will be most affected when they are rapidly growing, as such, prolonged waterlogging during the warmer spring period is where yield penalties will be most severe.

The HRZ of Victoria and Tasmania is particularly prone to waterlogging conditions, with high rainfall and sodic subsoils. This project is investigating ways in which the effects of waterlogging can be mitigated and enable farmers to make informed decisions about how they can manage their crops better under such circumstances. Under waterlogged conditions nitrogen is lost from soils through denitrification and leaching and a plant also has a limited ability to uptake nutrients during this period. Providing the crop with adequate nutrition following a waterlogged period is therefore of upmost importance to help the plants recover from this stress. This report will focus on ways to recover a waterlogged crop using different nutrition strategies.

METHOD

Four trials were established in locations that had experienced some degree of waterlogging throughout the season, shown in Table 1. The Hamilton trial was established at the SFS Victoria Point Road site, referred to as Hamilton in this report. The Hamilton, Vite Vite North and Hagley trials were small plot trials, utilising spare plots on SFS trial sites. The Streatham canola trial was located in a grower's paddock.

Table 1. Trial location, crop type, variety, sowing date and starting fertiliser.

Location	Crop Type	Variety	Sowing Date
Hamilton, VIC	Wheat	LRPB Trojan	7-May-21
Streatham, VIC	Canola	45Y28 RR	10-Apr-21
Vite Vite North, VIC	Faba Beans	PBA Samira	30-Apr-21
Hagley, TAS	Wheat	RGT Calabro	12-May-21

The treatments varied over the locations, with the main products used including urea, sulphate of ammonia (SOA), UAN and trace elements. The nitrogen in SOA is in a more readily available form than urea, meaning it can provide the crop with an immediate nitrogen source. This is compared with urea that can take up to 7-10 days to be in its most available form for plant uptake. SOA was applied in combination with urea to determine if this immediate uptake was beneficial when recovering a waterlogged crop. The trace elements applied across to the trials in Victoria was a product called Maximise (Zn, Cu, Mo, and B). In Tasmania the product Awaken (N, K2O, B, Cu, Fe, Mn, Mo, and Zn) was applied. These were used to ensure crops were not nutrient limited. In the wheat they were applied at least two weeks following the initial nitrogen recovery application when the crop was actively growing again, to improve efficiency of plant uptake.

Hamilton, VIC

This trial assessed 17 different nitrogen recovery treatments, as displayed in Table 2 as a summary. All treatments were replicated with and without trace elements, except the nil control. Each treatment was replicated at a full and reduced nitrogen rate. The trace elements were only applied at the first timing. The first application was applied on 27th August at GS 37, flag leaf just visible. The second application was applied eleven days later on the 7th of September at GS 41, flag leaf sheath extending. A third timing was required for the UAN (soil) application at the full rate, which was applied on 14th September, at GS47, flag leaf sheath opening. See Table 3 for further details on products, rates, and timings of applications. No nutrition had been applied to the trial prior to this, except 100 kg/ha MAP at sowing.

The Hamilton site experienced above average rainfall through the months of June and July and a moisture probe nearby at Yatchaw showed an average plant available water of 98% in July and 100% in both August and September (see Section 6 of this book, Climate and Soil Data). During these months the crop was rapidly growing, going through the stages of stem extension to booting. The timing of these wet conditions would likely would have reduced the yield potential of the crop.

Figure 1. Chlorosis, yellowing of leaves, a symptom of waterlogging observed at the Hamilton site in August.

Table 2. Summary of Hamilton trial treatments.

Trt. No.	Treatment	Applied N
1	Urea	Full rate (145 kg N/ha)
2	Urea + Trace elements	
3	Urea + SOA	
4	Urea + SOA + Trace elements	
5	UAN (soil)	
6	UAN (soil) + Trace elements	
7	UAN (foliar) + Urea	
8	UAN (foliar) + Urea + Trace elements	
9	Urea	Reduced rate (85 kg N/ha)
10	Urea + Trace elements	
11	Urea + SOA	
12	Urea + SOA + Trace elements	
13	UAN (soil)	
14	UAN (soil) + Trace elements	
15	UAN (foliar) + Urea	
16	UAN (foliar) + Urea + Trace elements	
17	Nil control	

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Table 3. Detailed list of treatment including Products, rates, and timings of applications at Hamilton. Each treatment was replicated with and without trace elements. They were applied at the first application timing only, 27th August at GS 37, flag leaf just visible.

Treatment		Application Date	Product	Rate/ha	Growth Stage
Full rate (Total applied 145 kg N/ha)	1	27-Aug-21	Urea	210 kg	GS 37
		7-Sep-21		105 kg	GS 41
	2	27-Aug-21	Urea	165 kg	GS 37
		27-Aug-21	SOA	100 kg	GS 37
		7-Sep-21	Urea	105 kg	GS 41
	3	27-Aug-21	UAN (soil)	115 L	GS 37
		7-Sep-21		115 L	GS 41
		14-Sep-21		115 L	GS 47
	4	27-Aug-21	UAN (foliar)	20 L	GS 37
		27-Aug-21	Urea	190 kg	GS 37
		7-Sep-21	Urea	105 kg	GS 41
Reduced rate (Total applied 85 kg N/ha)	5	27-Aug-21	Urea	125 kg	GS 37
		7-Sep-21	Urea	65 kg	GS 41
	6	27-Aug-21	Urea	80 kg	GS 37
		27-Aug-21	SOA	100 kg	GS 37
		7-Sep-21	Urea	60 kg	GS 41
	7	27-Aug-21	UAN (soil)	115 L	GS 37
		7-Sep-21	UAN (soil)	90 L	GS 41
	8	27-Aug-21	UAN (foliar)	20 L	GS 37
		27-Aug-21	Urea	105 kg	GS 37
		7-Sep-21	Urea	60 kg	GS 41
	9	Nil control			

Streatham, VIC

This trial looked at three methods of nutrition recovery displayed in Table 4. Applications were applied at one timing, GS67, flowering declining.

Table 4. Recovery canola at Streatham.

Trt	Date Applied	Product	Rate/ha
1	22-Sep-21	Urea	220 kg
2		Urea	175 kg
		SOA	100 kg
3		Urea	175 kg
		SOA	100 kg
		Trace elements	3 L
4	Nil control		

Rainfall at the Streatham site was above average in May, June, and July with a total of 206mm of rain falling across the three months. A moisture probe at a nearby site at Westmere, showed plant available water at its peak at 97% in August, up from 90% in July. It then begins to decline from September to the end of the season (see Section 7 of this book, Climate and Soil Data). The location of this trial was in a low-lying area of the paddock and the plants displayed visible symptoms of waterlogging, such as reduced plant growth and yellowing, particularly compared with other areas of the paddock (Figure 2).

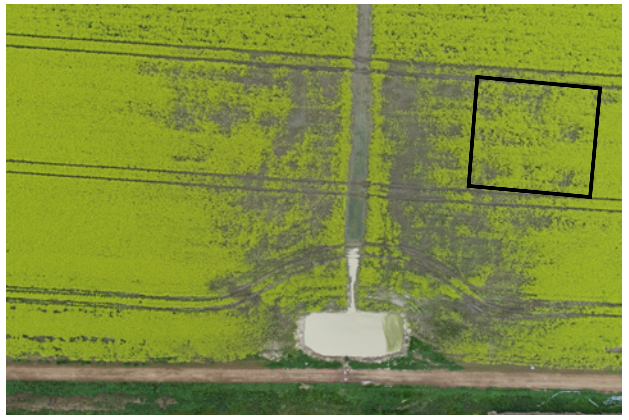

Figure 2. Aerial view of waterlogged area and trial location at Streatham.

Vite Vite North, VIC

The faba bean trial at Vite Vite North had five rates of urea applied at 10% flowering, which occurred in mid-August (Table 5). The application rates ranged from 0 to 240 kg/ha Urea. MAP was applied at sowing across the whole trial at a rate of 100 kg/ha.

Table 5. Recovery faba beans at Vite Vite North.

Trt	Date Applied	Urea/ha
1	19-Aug-21	0 kg
2		60 kg
3		120 kg
4		180 kg
5		240 kg

Rainfall at the Vite Vite North site was well above average in May, June, and July with a total of 254mm of rain falling across the three months. A moisture probe at Vite Vite showed plant available water was at 95% from mid-June to mid-July and then moved to 100% until mid-August, when it started to decline.

Hagley, TAS

The recovery wheat in Tasmania had seven treatments, as displayed in Table 6. Each treatment was replicated at a full and reduced nitrogen rate. The urea was applied over three timings, the 10th October when the crop was at GS 32 (flag minus 2), 28th of October at GS 39 (flag leaf fully emerged), and the 12th of November at GS 45 (boots swollen). The SOA was applied on the 17th of October at GS 33, and the trace elements eleven days later on the 28th. See Table 7 for further details on products, rates, and timings of applications. No nutrition had been applied to the trial prior to this, except 100 kg/ha MAP at sowing. Hagley received above average rainfall through July and August with a total rainfall of 218mm across the two months.

Table 6. Summary of treatments of the recovery wheat, Hagley.

Trt	Product	Applied N
1	Urea	Full rate (180 kg N/ha)
2	Urea + SOA	
3	Urea + SOA + Trace elements	
4	Urea	Reduced rate (100 kg N/ha)
5	Urea + SOA	
6	Urea + SOA + Trace elements	
7	Nil control	

Table 7. Detailed treatment list of products, rates, and timings of applications at Hagley.

Treatment		Application Date	Product	Rate/ha	Growth Stage
Full rate (Total applied 180 kg N/ha)	1	10-Oct-21	Urea	175 kg	GS 32
		28-Oct-21	Urea	175 kg	GS 39
		12-Nov-21	Urea	45 kg	GS 45
	2	10-Oct-21	Urea	130 kg	GS 32
		17-Oct-21	SOA	100 kg	GS 33
		28-Oct-21	Urea	175 kg	GS 39
		12-Nov-21	Urea	45 kg	GS 45
	3	10-Oct-21	Urea	130 kg	GS 32
		17-Oct-21	SOA	100 kg	GS 33
		28-Oct-21	Urea	175 kg	GS 39
		28-Oct-21	Trace elements	3 L	GS 39
		12-Nov-21	Urea	45 kg	GS 45
Reduced rate (Total applied 100 kg N/ha)	4	10-Oct-21	Urea	175 kg	GS 32
		28-Oct-21	Urea	45 kg	GS 39
	5	10-Oct-21	Urea	130 kg	GS 32
		17-Oct-21	SOA	100 kg	GS 33
		28-Oct-21	Urea	45 kg	GS 39
	6	10-Oct-21	Urea	130 kg	GS 32
		17-Oct-21	SOA	100 kg	GS 33
		28-Oct-21	Urea	45 kg	GS 39
		28-Oct-21	Trace elements	3L	GS 39
	7	Nil control			

RESULTS & DISCUSSION

Hamilton, VIC

The wheat at the Hamilton site began to show waterlogging symptoms in July and these conditions continued through August while the crop was undergoing tillering and stem extension. This corresponds with the moisture probe at Yatchaw which showed 98% plant available water through July and at full capacity at 100% in August.

The nil control was not replicated under the factorial design, and as such has not been statistically analysed with the results below. The AOV means analysis did not result in any significant differences in grain yield. The average results for the nil treatment were a grain yield of 4.5 t/ha, grain protein of 11.4% and a test weight of 76.5 kg/hL.

The type of product used did not result in any significant differences in NDVI results taken post applications, grain yield or grain quality (Table 8). The average grain yield across treatments was 5.5 t/ha and grain protein 13%. The rate of fertiliser applied had a significant effect on grain protein, with the full rate resulting in an average protein of 13.4%, compared with 12.5% for the reduced rate treatments. Provided applications were not applied too late in season, a grain protein value of 10.8% or above is a good indication that nitrogen was not limiting yield. In this trial, where even the nil control produced a protein of 11.4%, this would indicate that nitrogen was not a limiting factor. There were no other differences between the two nitrogen rates.

Trace elements went out at the first application timing across half the treatments. NDVI readings taken 26 and 38 days after application show a significant increase in canopy greenness where trace elements were applied, however this did not translate into any differences in grain yield or quality.

Post-harvest soil tests taken in early March in the 0-60 cm zone, indicate there are minimal differences in soil nitrogen between total rates of nitrogen applied (Figure 1). With a significantly higher grain protein in the full versus reduced rate treatments, it could be suggested that these soil nitrogen differences have been lessened, as the nitrogen has been used for grain protein. The biggest difference can be seen where urea was applied standalone, where the full rate measured a higher soil nitrogen by on average 13 kg N/ha. A trend however can be seen in Figure 3 by product. Urea and UAN applied to the soil had the highest residual soil nitrogen, followed by urea + SOA, then urea + UAN foliar applied. The nil nitrogen areas had the lowest soil nitrogen at 44 kg N/ha, indicating that where nitrogen was applied, some was returned to the soil for the following season.

Table 8. Wheat recovery trial at Hamilton by factors; product, fertiliser rate and trace elements.

	NDVI 23-Sep-21	NDVI 5-Oct-21	Yield (t/ha)	Protein (%)	Test Weight (kg/hL)	Screenings (%)
Product						
Urea	0.74 -	0.73 -	5.6 -	13.3 -	75.0 -	1.8 -
Urea + SOA	0.74 -	0.71 -	5.6 -	12.8 -	75.3 -	1.7 -
UAN (soil)	0.74 -	0.71 -	5.6 -	12.7 -	75.9 -	1.3 -
UAN (foliar) + Urea	0.75 -	0.72 -	5.3 -	13.0 -	75.8 -	1.8 -
p-value	0.9	0.09	0.6	0.09	0.5	0.5
LSD	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Fertiliser Rate						
Full	0.74 -	0.72 -	5.6 -	13.4 a	75.3 -	1.6 -
Reduced	0.75 -	0.71 -	5.4 -	12.5 b	75.7 -	1.6 -
p-value	0.4	0.054	0.2	0.002	0.4	0.9
LSD	n.s.	n.s.	n.s.	0.3	n.s.	n.s.
Trace Elements						
With traces	0.75 a	0.72 a	5.4 -	12.9 -	75.4 -	1.8 -
Without traces	0.74 b	0.71 b	5.7 -	13.0 -	75.6 -	1.5 -
p-value	0.02	0.002	0.4	0.7	0.8	0.5
LSD	0.0062	0.003	n.s.	n.s.	n.s.	n.s.

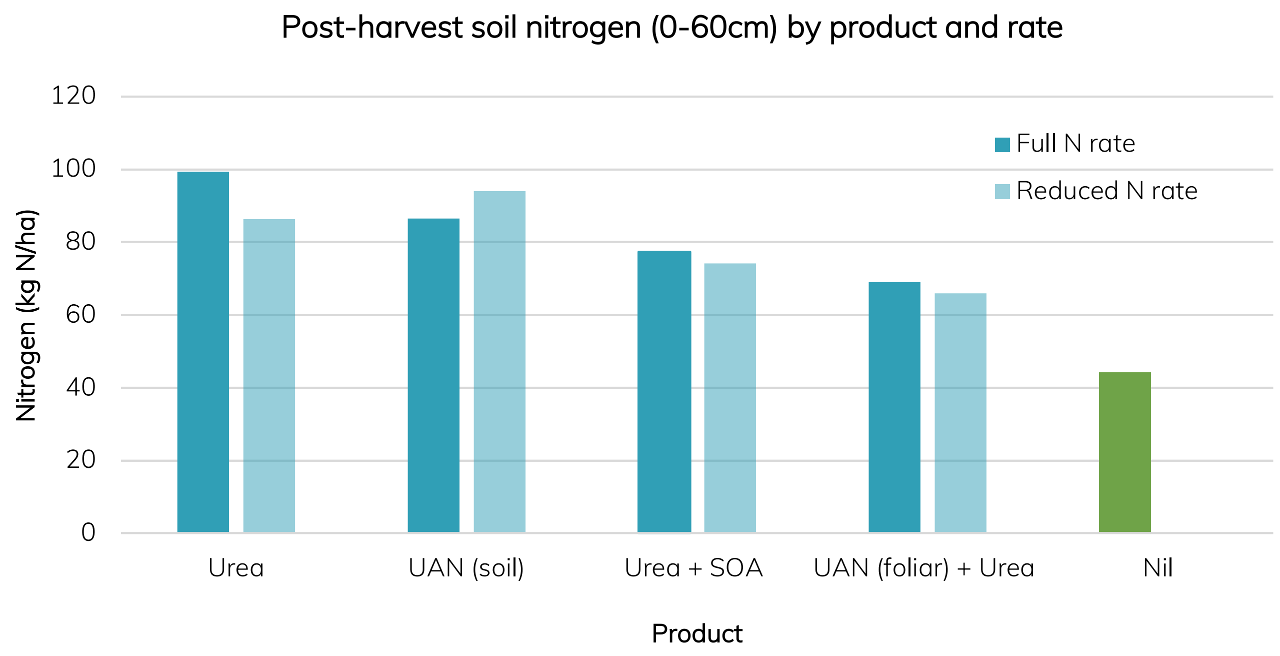

Figure 3. Post-harvest soil test results by product and rate of nitrogen applied in the Hamilton trial.

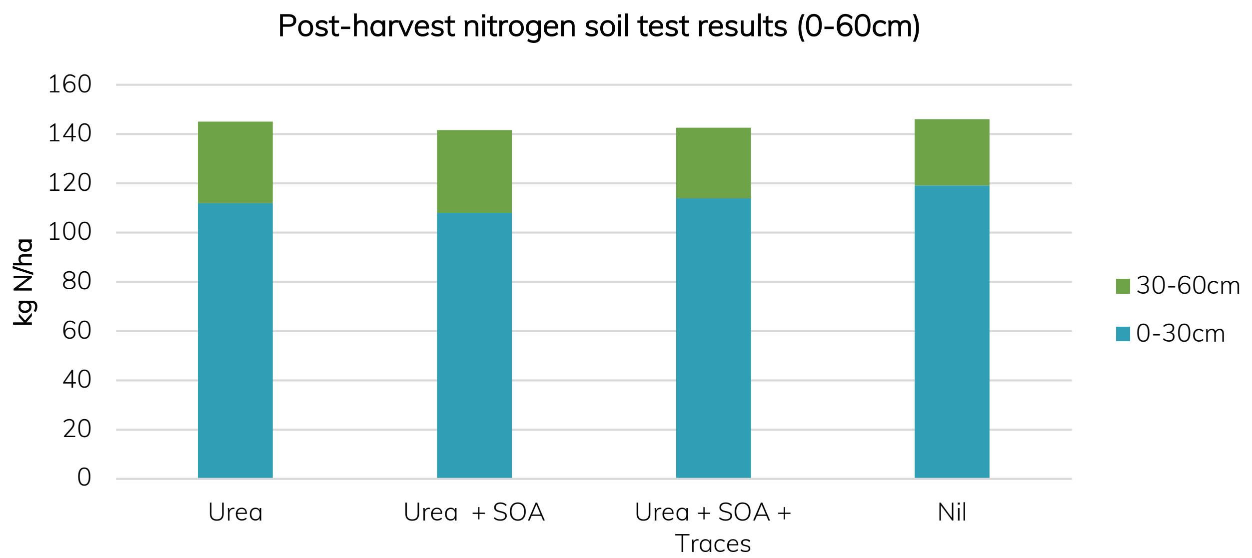

Figure 4. Post-harvest nitrogen soil test results across the four treatments at Streatham. Results are from 0-30 cm and 30-60 cm zones.

Streatham, VIC

Peak nitrogen requirements in canola are from the start of flowering to the end of pod formation. The application timing, towards the end of flowering for this trial, was very late in-season compared to standard practice. This was one of the first timings that the paddock was trafficable and considered an option.

The applications in this trial did not result in any differences in grain yield or oil content (Table 9). A target biomass for optimal yield potential in canola is considered around 5 t/ha by the start of flowering. An average biomass of 5.3 t/ha was measured towards the end of flowering, on the day nutrition applications were made. The critical period for yield determination in canola is 300-degree days from the start of flowering, which is approximately 30 days in the south-west Victorian environment. Moisture probes in the area showed plant available water to be at its peak in August. Hence, the timing of waterlogging in this situation, may have reduced negative effects on grain yield, as despite appearing visually impacted by waterlogged soils, the trial overall yielded well, with an average yield of 4.1 t/ha.

Table 9. Canola recovery yield and oil content Streatham.

Trt	Product	Yield (t/ha)	Oil (%)
1	Urea	3.9 -	44.0 -
2	Urea + Gran Am	3.8 -	45.0 -
3	Urea + Gran Am + Traces	4.7 -	46.2 -
4	Nil	4.1 -	46.5 -
	p-value	0.08	0.06
	LSD	n.s.	n.s.

Post-harvest soil tests were taken in late February to determine if the additional nitrogen applied would remain available to the crop in the following season. The soil test results showed no significant differences in total nitrogen between any of the treatments, including the nil (Figure 4).

Vite Vite North, VIC

At Vite Vite North, the waterlogging occurred in the very early stages of flowering in the faba beans. Applying nitrogen to determine if it could help mitigate the effects of waterlogging did not result in any significant differences in grain yield (Table 10). Pulses are typically not well suited to waterlogged conditions. Of all the pulses, faba beans however are considered the most tolerant to waterlogging (GRDC 2017). The trial reached full flower towards the end of August. Yields achieved in this trial would indicate that although soils were at field capacity through July and August, and some visual signs of waterlogging were evident, the impact of waterlogging on final grain yield has not been severe.

Table 10. *Recovery faba beans at Vite Vite North*

Trt	Urea (kg/ha)	Yield (t/ha)
1	0	7.9 -
2	60	8.3 -
3	120	8.6 -
4	180	7.5 -
5	240	7.8 -
	p-value	1.12
	LSD	n.s.

The post-harvest soil tests indicate that the nitrogen available in the soil in the 0-60 cm zone was above 120 kg N/ha across all treatments (Figure 5). The nil control had the highest amount of nitrogen remaining in the soil, with a total of 146 kg N/ha. On average the nil treatment had 22 kg N/ha more nitrogen compared with treatments where applications had been made. With yields that were insignificant across treatments, it could have been expected that treatment 5, which had the highest urea rate applied at 240 kg/ha, would have had a higher soil nitrogen than other treatments. It could be that the plants have been more efficient at fixing their own nitrogen where no nitrogen has been applied. This trial has shown that faba beans are able to still produce exceptional yields and leave a substantial amount of nitrogen in the soil for use in the following year, despite going through waterlogged conditions.

Hagley, TAS

The average yield for wheat in Tasmania was 9.4 t/ha, this average included a nil treatment which was almost 2 t/ha lower than the nitrogen treatments (Table 11). Where higher rates of nitrogen were applied a significant increase in grain yield was achieved in two of the three treatments. Urea + SOA + trace elements did not result in a yield increase compared with the reduced rate treatments. While yield did not consistently increase with higher rates of nitrogen applied, grain protein did. Table 6 shows grain protein significantly increased between nil, reduced rate, and full rate treatments. The average protein value across all treatments of 7.7% indicates that nitrogen may have been a limiting factor to grain yield. The full rate applications had the highest grain protein, ranging

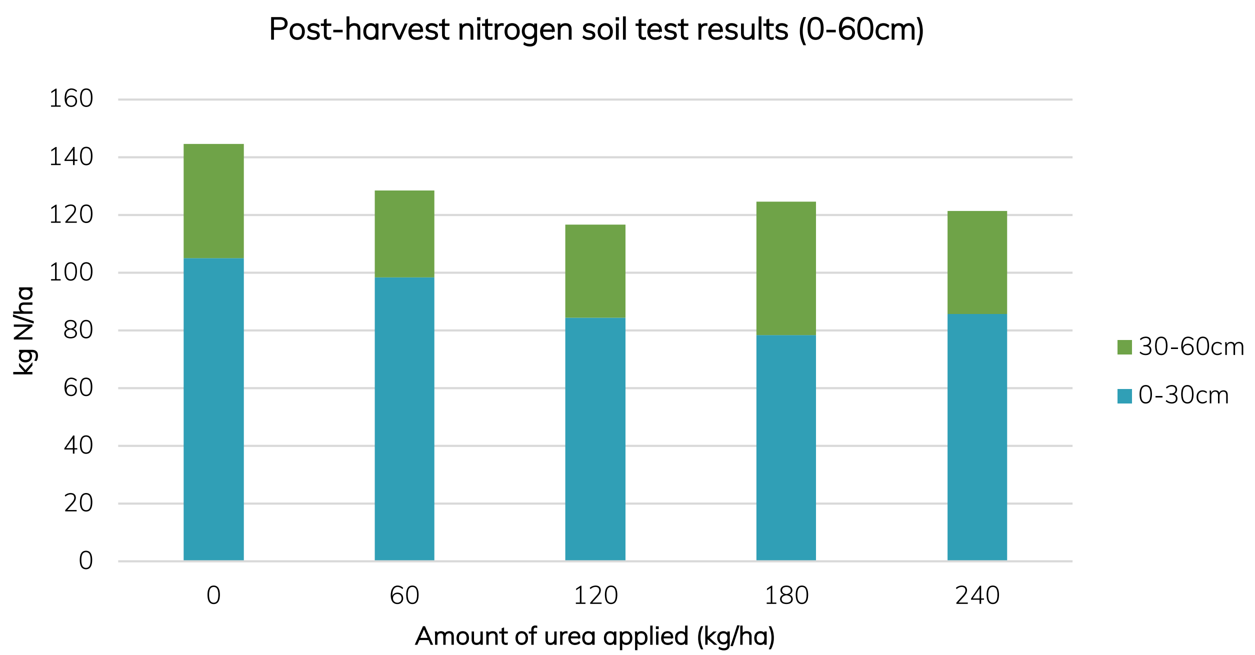

Figure 5. *Post-harvest nitrogen soil test results across the five treatments at Vite Vite North. Results are from 0-30 cm and 30-60 cm zones.*

Table 11. *Grain yield and quality results for the wheat trial at Hagley.*

	Treatment	Yield (t/ha)	Protein (%)	Test Weight (kg/hL)	Screenings (%)
Full rate	Urea	10.3 a	8.45 a	76.4 a	0.7 -
	Urea + SOA	10.2 a	8.13 a	76.3 a	0.7 -
	Urea + SOA + Trace elements	9.6 b	8.40 a	75.8 ab	0.9 -
Reduced rate	Urea	9.6 b	7.50 b	75.6 ab	0.7 -
	Urea + SOA	9.3 b	7.50 b	75.2 b	0.8 -
	Urea + SOA + Trace elements	9.6 b	7.40 b	75.6 ab	0.7 -
	Nil	7.4 c	6.98 c	75.2 b	0.6 -
p-value		<0.001	<0.001	0.046	0.2
LSD		0.5	0.35	0.9	n.s.

from 8.1 to 8.4%. The test weight shows a trend of declining where lower rates of nitrogen were applied. In this trial, total nitrogen was a bigger influence on grain yield and protein compared with product type. These results show that in this situation applying nitrogen, in any combination of products or rates has increased the yield and grain protein when compared to the nil control.

CONCLUSION

Understanding the growth stage of plants during a waterlogging period is critical in determining potential yield impacts. Despite presenting some waterlogging symptoms, faba beans and canola yielded exceptionally well in these trials. Average yields of 8 t/ha were recorded for the faba beans and 4.1 t/ha in canola, noting again that the faba bean trial was in small plots and the canola an area from a grower's paddock. The wheat at Hagley also yielded well, with an average grain yield of 9.4 t/ha. These yields are likely attributed to the timing and severity of waterlogging in relation to the crop's physiological development stage. The type of product used did not influence grain yield in any of the trials. There was however a trend in total soil nitrogen by product at Hamilton, where post-harvest soil tests were taken. The Hagley site was the only trial to present a yield response by rate of nitrogen, with higher rates of nitrogen applied improving grain yield.

ACKNOWLEDGMENTS

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